CLEAN VERSION OF AMENDMENTS

In the Specification:

Replace the paragraph starting on Page 1, line 6, with:

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The present application is a continuation of pending Application No. 09/433,657 filed 11/3/99 on behalf of Rosenberg et al., which is a continuation of Application No. 08/664,086, filed June 14, 1996, now Patent No. 6,028,593, which is a continuation-in-part of U.S. Patent Application Nos. 08/566,282, filed December 1, 1995, now Patent No. 5,734,373; and 08/571,606, filed December 13, 1995, now Patent No. 6,219,032; and where said Application No. 08/664,086 claims the benefit of provisional application No. 60/017,803, filed May 17, 1996, all of which are incorporated herein by reference for all purposes.

Replace the paragraph starting on Page 9, line 30, with:

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User object 34 is preferably coupled to sensors 28 and actuators 30 by a mechanical apparatus which provides a number of degrees of freedom to the user object. Such a mechanical apparatus can take a variety of forms, from a simple rotary joint or linear coupling allowing a single degree of freedom, to a complex mechanical linkage allowing multiple degrees of freedom to the user object. Examples of mechanical apparatuses are described in Patent Nos. 5,576,727; 5,731,804; 5,767,839; 5,721,566; and 5,805,140, all of which are hereby incorporated by reference herein. Preferred embodiments of mechanical apparatuses suitable for sporting simulations disclosed herein are described subsequently with reference to Figures 14-18.

Replace the paragraph starting on Page 11, line 3, with:

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In the described embodiment, host computer system 12 implements a host application program with which a user 22 is interacting via peripherals and interface device 14. For example, the host application program can be a video game, medical simulation, scientific analysis program, or even an operating system or other application program that can utilize force feedback. Typically, the host application provides images to be displayed on a display output device, as described below, and/or other feedback, such as auditory signals. For example, a graphical user interface for an operating system is described in greater detail in Patent No. 6,219,032, which is hereby incorporated by reference herein.

Replace the paragraph starting on Page 13, line 3, with:

An advantage of the present embodiment is that low-bandwidth serial communication signals can be used to interface with interface device 14, thus allowing a user to directly use a standard built-in serial interface of many low-cost computers. Alternatively, a parallel port of host computer system 12 can be coupled to a parallel bus 24 and communicate with interface device using a parallel protocol, such as SCSI or PC Parallel Printer Bus. In a different embodiment, bus 24 can be connected directly to a data bus of host computer system 12 using, for example, a plug-in card and slot or other access of computer system 12. For example, on an IBM AT compatible computer, the interface card can be implemented as an ISA, EISA, VESA local bus, PCI, or other well-known standard interface card. Other types of interfaces 14 can be used with other computer systems. In another embodiment, an additional bus 25 can be included to communicate between host computer system 12 and interface device 14. Since the speed requirement for communication signals is relatively high for outputting force feedback signals, a single serial interface used with bus 24 may not provide signals to and from the interface device at a high enough rate to achieve realistic force feedback. Bus 24 can thus be coupled to the standard serial port of host computer 12, while an additional bus 25 can be coupled to a second port of the host computer system, such as a "game port" or other port. The two buses 24 and 25 can be used simultaneously to provide an increased data bandwidth. Such an embodiment is described in greater detail in Patent No. 5,691,898, which is hereby incorporated by reference herein.

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Replace the paragraph starting on Page 17, line 7, with:

Other types of interface circuitry 36 can also be used. For example, an electronic interface is described in U.S. Patent No. 5,576,727, assigned to the same assignee as the present application, and which is hereby incorporated by reference herein. The interface allows the position of the mouse or stylus to be tracked and provides force feedback to the stylus using sensors and actuators. Sensor interface 36 can include angle determining chips to pre-process angle signals reads from sensors 28 before sending them to the microprocessor 26. For example, a data bus plus chip-enable lines allow any of the angle determining chips to communicate with the microprocessor. A configuration without angle-determining chips is most applicable in an embodiment having absolute sensors, which have output signals directly indicating the angles without any further processing, thereby requiring less computation for the microprocessor 26 and thus little if any pre-processing. If the sensors 28 are relative sensors, which indicate only the

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change in an angle and which require further processing for complete determination of the angle, then angle-determining chips are more appropriate.

Replace the paragraph starting on Page 18, line 28, with:

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Power supply 40 can optionally be coupled to actuator interface 38 and/or actuators 30 to provide electrical power. Active actuators typically require a separate power source to be driven. Power supply 40 can be included within the housing of interface device 14, or can be provided as a separate component, for example, connected by an electrical power cord. Alternatively, if the USB or a similar communication protocol is used, interface device 14 can draw power from the bus 24 and thus have no need for power supply 40. Such an embodiment is described in greater detail in Patent No. 5,691,898.

Replace the paragraph starting on Page 19, line 4, with:

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Safety switch 41 can be included in interface device 14 to provide a mechanism to allow a user to override and deactivate actuators 30, or require a user to activate actuators 30, for safety reasons. Certain types of actuators, especially active actuators such as motors, can pose a safety issue for the user if the actuators unexpectedly move user object 34 against the user with a strong force. In addition, if a failure in the control system 10 occurs, the user may desire to quickly deactivate the actuators to avoid any injury. To provide this option, safety switch 41 is coupled to actuators 30. In one embodiment, the user must continually activate or close safety switch 41 during operation of interface device 14 to activate the actuators 30. If, at any time, the safety switch is deactivated (opened), power from power supply 40 is cut to actuators 30 (or the actuators are otherwise deactivated) as long as the safety switch is deactivated. Examples of safety switches are described in Patent No. 5,691,898.

Replace the paragraph starting on Page 22, line 31, with:

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For example, a kinematic equation which calculates a force based on the velocity of the user object multiplied by a damping constant can be used to determine a damping force on the user object. This type of equation can simulate motion of object 34 along one degree of freedom through a fluid or similar material. A procedure for calculating a damping force on object 34 is described in Patent No. 5,767,839, which is hereby incorporated by reference herein. For example, a damping constant can first be selected which indicates the degree of resistance that

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object 34 experiences when moving through a simulated material, such as a liquid, where a greater number indicates greater resistance. For example, water would have a lower damping constant than oil or syrup. The host computer recalls the previous position of user object 34 (along a particular degree of freedom), examine the current position of the user object, and calculate the difference in position. From the sign (negative or positive) of the difference, the direction of the movement of object 34 can also be determined. The force is then set equal to the damping constant multiplied by the change in position. Commands that controlled an actuator based on this algorithm would produce a force proportional to the user object's motion to simulate movement through a fluid. Movement in other mediums, such as on a bumpy surface, on an inclined plane, etc., can be simulated in a similar fashion using different methods of calculating the force.

Replace the paragraph starting on Page 26, line 23, with:

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In an alternate embodiment having host computer 12 directly control force feedback, a local microprocessor 26 (as shown in Figure 2) can be included in interface device 14 to assist in relaying sensor and actuator data to and from the host and for commanding forces to be output as long as there is no change in forces. This type of embodiment is not a "reflex" embodiment as described in Figure 4 since forces output by interface device 14 are dependent on active and continuous control from the host computer. Such an embodiment is described in greater detail in Patent Nos. 5,739,811 and 5,734,373, both incorporated by reference herein. For example, in step 80 above, the host computer can check if there is a change in force required on user object 34 depending on the above-described parameters. If not, then the host need not issue a low-level command, since local microprocessor could continue to issue the previous low-level command. The local microprocessor 26 can also convert a low-level command to an appropriate form before it is sent to actuators 30.

Replace the paragraph starting on Page 27, line 28, with:

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The process of Figure 4 is suitable for low speed communication interfaces, such as a standard RS-232 serial interface. However, the embodiment of Figure 4 is also suitable for high speed communication interfaces such as USB, since the local microprocessor relieves computational burden from host processor 16. In addition, this embodiment can provide a straightforward command protocol, an example of which is described with respect to Patent No.

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5,734,373, incorporated by reference herein, and which allows software developers to easily provide force feedback in a host application.

Replace the paragraph starting on Page 30, line 1, with:

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If no change in the type of force is currently required in step 110, then the process returns to step 106 to update the host application and return to step 110 to again check until such a change the type of force is required. When such a change is required, step 112 is implemented, in which host computer 12 determines an appropriate host command to send to microprocessor 26. The available host commands for host computer 12 can correspond to an associated force routine implemented by microprocessor 26. For example, different host commands to provide a damping force, a spring force, a gravitational pull, a bumpy surface force, a virtual obstruction force, and other forces can be available to host computer 12. These host commands can also include a designation of the particular actuators 30 and/or degrees of freedom which are to apply this desired force on object 34. The host commands can also include other command parameter information which might vary the force produced by a particular force routine. For example, a damping constant can be included in a host command to designate a desired amount of damping force, or a direction of force can be provided. The host command may also preferably override the reflex operation of the processor 26 and include low-level force commands directly sent to actuators 30. A preferred command protocol and detailed description of a set of host commands is described in Patent No. 5,734,373. These commands can include direct host commands, "reflex" commands, and custom effects. Each direct host command preferably includes parameters which help the host specify the characteristics of the desired output force and may include a specified force routine. "Reflex" commands, in contrast, provide conditions to the microprocessor so that the desired force is output when the conditions are met, such as when a specified button is pressed by the user. Custom effects can be provided to the microprocessor 26 by the host and then commanded to be output. For example, the host computer can download to the microprocessor a set of force values (a force profile) as a "force profile file" or other collection of data using a host command LOAD_PROFILE; a separate host command PLAY_PROFILE could then be sent to instruct the microprocessor to output the downloaded force profile as forces on user object 34, or when a condition occurs, etc. For example, a force profile file can include an array of force values, size information about the size of the data, and timing information for when to output the various force values.

Replace the paragraph starting on Page 30, line 1, with:

a12

Embodiments using a local microprocessor 26 to implement reflex processes is described by Patent Nos. 5,739,811 and 5,734,373, both assigned to the assignee of this present application, and both hereby incorporated by reference herein.

Replace the paragraph starting on Page 40, line 4, with:

a13

Figures 6a-6h show how paddle object 220 interacts with a moving ball object 206 as ball object 206 collides with the paddle object. In Figure 6a, ball 206 first impacts paddle 220. Preferably, an initial force is applied to user object 34 in the appropriate (corresponding) direction of the ball's movement. In Figures 6b and 6c, ball 206 is moving into the compliant paddle or "sling." Preferably, a force based on a simulated mass of ball 206 (and/or other simulated conditions) is felt by the user through user object 34 which is appropriate to the simulated velocity of the ball (and/or the paddle), the simulated compliance of the paddle (and/or the ball), and the strength and direction of simulated gravity. In a local microprocessor embodiment, as described in Figure 4, these factors (and other desired physical factors) can preferably be set using a host command with the appropriate parameters, as described in Patent No. 6,219,032. For example, parameters of objects can be specified and simulated such as mass of the ball, velocity of the ball, the strength of gravity, the direction of gravity, the compliance or stiffness of the paddle object 220, damping forces to the collision between the ball and paddle, a simulated mass of the paddle 220, and other parameters to control other physical aspects of the computer environment and interaction of objects. In addition, the ball 206 can be displayed as a compressed object when it impacts paddle 220, with, for example, an oval or elliptical shape. Also, the parameters such as the compliance and/or damping of the paddle might be allowed to be adjusted by the user with other input 39 or an additional degree of freedom of a user object 34 manipulated by the user.

N.E. (Not in line)

Replace the paragraph starting on Page 40, line 4, with:

NE

An interface apparatus providing two linear (X and Y) degrees of freedom to user object 34 as well as a rotating ("spin") third degree of freedom about a Z axis is quite suitable for the paddle-ball implementation. Linear degree of freedom apparatuses are disclosed in Patent Nos. 5,721,566 and 5,805,140, previously incorporated herein, and further embodiments of such are described below.